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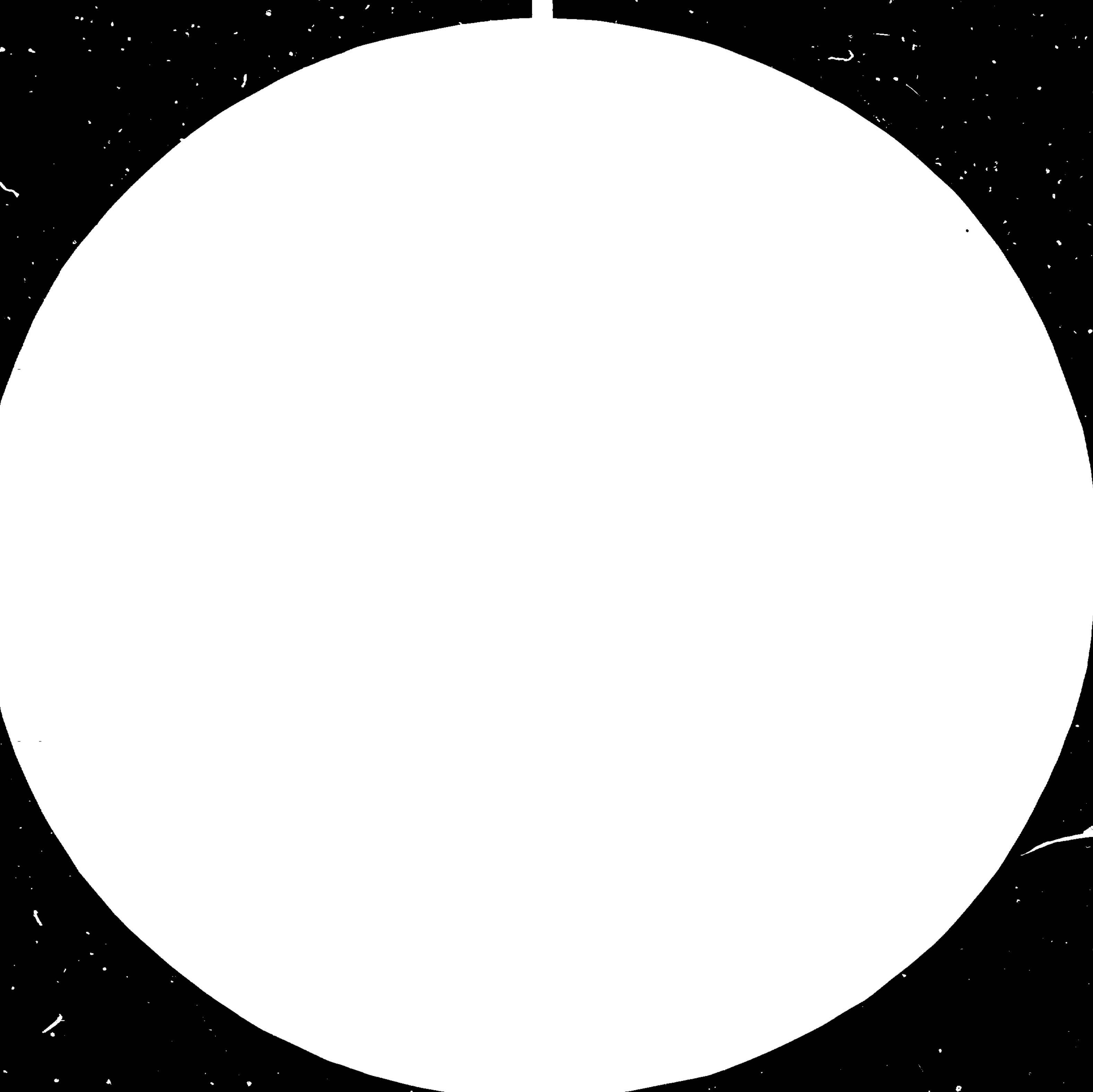

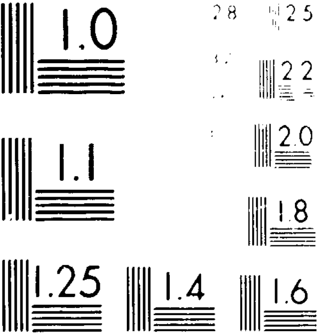

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EXCHANGE OF VIEWS WITH EXPERTS ON THE IMPLICATIONS OF TECHNOLOGICAL ADVANCES IN MICRO-ELECTRONICS FOR DEVELOPING COUNTRIES

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FUTURE OF ELECTRONICS AND TECHNOLOGY TRANSFER*

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FUTURE OF ELECTRONICS AND TECHNOLOGY TRANSFER

1. Electronics in general.

In every industrialised country in the world, electronics as an industry occupies a prime place and contributes quite substantially to the GNP of these countries. The electronics systems, the electronic components, the raw materials associated with these components, the associated production equipments, have all created an explosive situation in business circles of these countries. This situation has resulted in the spectacular growth of national economy in some of these countries.

The supreme examples of these are, USA, Japan and to a lesser extent, Western Europe. The total world consumption of the electronic end equipment is expected to be $ 200,000 million by 1985, and the components consumption is predicted to be $ 45,000 million by the same year. USA and Japan enjoy a substantial portion of this world market. In India, the production was about $ 600 million in '78, a very small percent of this world production for all types of electronics systems.

The electronics industry, as such, comes after steel and chemicals which are heavy industries. This industry has enjoyed and continues to enjoy, over the years, a very rapid growth rate. Between 1970 and 197[illegible], this growth rate has been about 11.2% per annum and is expected to touch 20% by 1985. The components have also shown a similar growth rate.

The electronics industry is labour intensive whenever the end products are electronic equipments, but capital intensive in component manufacture. This capital investment is not very large however, when compared with steel or other heavy industries. A steel plant may cost

US $ 200 million whereas a sophisticated, state-of-art, LSI plant may cost about $ 60 million. The electronics industry further enjoys a low capital to output ratio.

This industry, however, suffers from rapid obsolescence because of rapid changes in technology. It is the Research and Development efforts which has been responsible for this rapid and spectacular growth and yet it is the same R & D which is responsible for rapid obsolescence. It is therefore clear that, especially in this industry, a strong R&D base is an absolute necessity even in cases of bought technologies. This R&D assumes enormous importance in the case of semiconductors and Large Scale Integrated circuits (LSI) which are the future of electronics.

India, unfortunately, in spite of enough infrastructure in men and materials, has given a go by to many of the changes taking place in electronics. In some fields, especially in manufacture, we are conveniently ten years behind and in some R&D institutions, perhaps five years behind. Overall, it is a sad state to be in, especially in electronics field.

2. Semiconductor Devices - Electronic Components.

Electronic components, particularly active components, constitute the basic infrastructure for all electronic systems industry. For the first fifty years of this century, before the advent of the transistor, the basic building block of all electronic systems was the vacuum tube which is still being used in many applications. The transistor which came on the scene in the 1950's, marked an enormous change in the basic character of the electronic equipment industry. Production processes, costs of production and hence the market, reduced power consumption, increased reliability, reduction in size and weight of these devices and components, introduced a tremendous change in the electronic equipment industry with the result that electronics became a major industry in every industrial economy. With the advent of these transistors or solid state devices (semiconductor devices), the R&D in these areas received such an impetus that the technological changes resulting from such an R &D resulted further in dramatic reduction in costs of these devices.

Furthermore, because of this intense R&D efforts, it was realised that it was possible to design a set of optical, chemical and physical processes by which the entire electronic circuits could be made on a single piece of silicon measuring .04" x .04". These were called "Integrated Circuits" and were introduced in 1965, and they consisted of a few transistors and resistors. Thus, the philosophy of integration towards realisation of complex electronic circuits and systems came into being.

As the technology of this integration advanced, it became possible, by the end of 60's to attain levels of integration where as many as 1000 transistors and other components were integrated to form complete electronic subsystems and systems. By the early 70's, this integration was advanced to a stage when 4000-5000 transistors could be integrated. By the end of this decade (1980), due to rapid advancements in technology, it would be possible to integrate 100,000 elements in a single piece of Silicon measuring .2" x .2" which could be a complete electronic system.

3. Large Scale Integration (LSI) and Very Large Scale Integration (VLSI)

LSIs and VLSIs, thus, ushered in a new era in electronic systems. The systems which could not be attempted earlier because of weight, reliability and cost considerations, have become possible with LSIs. The LSI is no longer a single electronic component like, say, a transistor. It is a complete electronic system or a subsystem by itself. This has become possible due to lowering of costs due to the integration.

What LSIs have done in the past few years, can be understood by citing a few examples. The hand-held calculator of today has become possible with LSI and similarly the electronic wrist watch. In the computer and data processing industry, the introduction of high density solid state memories and microprocessors has made it possible to replace existing conventional control circuits and to introduce the home computer at a substantially reduced cost. Over the next few years, these LSIs will form part of all Telecommunication circuits. Defence and Aerospace industries will resort to LSIs because of higher reliability and lower weight.

Thus, LSIs have become basic building blocks for the entire electronic systems industry. With the LSI, there is no limit to the possible innovations in the equipment industry. In fact, LSIs occupy the same position as steel in the building industry. By the end of this century, LSI plants will be considered very crucial in any industrialised country.

4. Microprocessors and Microcomputers - A Technology Assessment.

One of the most significant contributions made in the recent years towards Integrated Electronics is the Microprocessor, which is an LSI. The advent of this LSI marked an important turning point in the development of digital computers. This microprocessor is a complete processor for calculators and small computers integrated in a single chip of silicon. With additional memory built on the same chip, this microprocessor becomes a microcomputer. In short, we have an extremely small (not possible to see with the naked eye) inexpensive computer having significant processing power and versatility that stored programme control and data processing can be extended even to the smallest electronic instrument, say, a digital multimeter.

Solid State Electronics, that is Integrated Electronics, led by micro-computers, is now having a substantial impact on many diverse fields of human activity ranging from industrial process control to health care and transportation. There is no necessity for large centralised computers. They will be decentralised with many microcomputer installations on a closed network. It is very difficult to assess, right now, as to what the microprocessor would do and in what field. It looks as if the microprocessors, because of lower costs and ever increasing power, can be used in almost all applications.

The direct and indirect effects of this technology on society have not been spelt so far even in the Western countries. As far as one can see, the primary effects are immense. It is noted by some social historians that the inexpensive microprocessor may well rank as the third major cultural revolution next to automobiles and television. These early revolutions have had their beneficial and harmful effects on society. Microprocessors have to be still assessed.

In India, we have to yet understand the full implications of this microprocessor. It is often said that this is a very sophisticated technology and is not relevant to a developing economy. This is not true. As a matter of fact, some of the serious problems in transport and communications which will be faced by us by the end of the century, can be solved by some of these concepts. This technology is not a luxury but a necessity as we will show later. Microprocessors are here to stay.

5. Technology Developments in LSI - Microprocessor.

The criteria for judging the future of LSI will be mainly speed of the device, power dissipation of the devices and size of the device. These will determine the speed, power, chip complexity (LSI is often known as the 'chip') and hence the cost of the micro-processor, or any other circuit realized using the above technology. There are many competing technologies which are considered appropriate for realising LSI. The choice is essentially determined by the ease with which the circuit functions could be realised.

Generally, LSIs are made in batches, and there are as many as 200-300 unit processes which are performedon these batches in different environments and in different equipments. The starting point is silicon wafer of 3" or 4" diameter and about .02" thick and as many as 20 - 40 wafers constitute a batch. Depending on the complexity of the devices to be made, each of these silicon wafers may contain 100 to 150 devices. After the whole sequence of processes, the devices are packaged and electrically tested and on testing, as many as fifty to seventy good devices may be obtained. This "Yield" or the number of good devices available per wafer is the most important criterion for establishing a successful LSI technology and on this yield depends the cost, economic viability etc. of the plant. The more difficult the LSI technology, the less will be the yield per wafer. Therefore, developing countries who want to enter this field, have to be careful about the choice of these technologies.

The LSI's are formed by means of a series of photoengraving or photolithography steps that control the selective doping of silicon lattice either with Boron (P type) or Phosphorus (N type) to form diodes, transistors, resistors etc. Most of the LSI's are made for digital functions like memories, microprocessors. These subsystems contain a series of identical on-off switches or identical storage elements. These on-off switches are either made with what are called bipolar transistors or MOS transistors (Metal Oxide Semiconductor). Thus, the LSI's are either bipolar LSI's or MOS LSI's.

In the initial stages, when cost was the main consideration, MOS type of LSIs were used and wherever the speed of operation was a consideration, Bipolar LSI's were used. In the recent times, due to advances in technology, MOS LSI's are made with increasing speed whereas Bipolar LSI's are being made with lesser cost. Some of the complexities of LSI, and competing technologies of LSI are shown in the slides.

It is safe to assume that these technologies as we understand them at present namely bipolar and MOS technologies, will stay till the 90's for making microprocessors. It is very important to note that this is still a young field, only fifteen years old, and there would be conceivably radically new approaches. Thus, for the nineties, our predictions are conservative.

6. <u>The Micro-computer, Microprocessor Hardware</u>.

To realise the full implications of these LSI's, it is necessary to know a little about the hardware configurations of these microprocessors. Such a configuration is shown in the slide. The hardware should be analysed with the following criteria, computer costs, microcomputer speed (Instruction Cycle), microcomputer word length and the developments in mass memories. Some of these aspects are shown in the slide.

The cost of the microprocessor chip is dependant on the area of silicon. Most of the earlier microprocessors and present day ones have an area of 30 - 40K mil^2. The future generations will have more memory in the chip and the chip sizes will be 50 - 60K mil^2. In large volumes, the chip prices will be about $ 4/- and by 1985, they will be $ 2/-. It is therefore clear that such a low cost will have an enormous impact particularly in new application areas of electronics. The system cost, that is the microprocessor, power supply, chassis, peripherals etc. may cost more, say, two orders of magnitude from the LSI chip. However, as most of the components, especially peripherals etc. will increasingly use LSI's, the system costs also will drop down appreciably.

The typical instruction cycles and power levels for different processors are shown in the slide. A typical electronic system controlled by Microprocessor is also shown in the diagram. The peripherals, like printers, cassettes etc. are as important as the main system itself as they provide the man machine interface. With the advent of LSI, and with our increasing ability to pack more number of devices on a chip, voice operated systems and word processors are becoming a reality - eg. automatic typewriters, voice operated vending machines etc.

In conclusion, we can fairly predict that by the nineties, the microprocessor and micro-computer will have achieved approximately 1000 times in functional density and 50 times less the present day speeds. With these spectacular advancements, nobody can say where these will be useful and what exactly their impact will be on society.

7. The Micro-computer, Microprocessor Software.

Software allows you to programme a machine as per your requirements or you can operate the machine by a series of instructions called the "programme". All along, the cost of a computer was primarily dependant on hardware to 80% and software to 20%. This situation is reversed as clearly indicated by the drastic reduction in prices of computer hardware due to LSI. The software assumes more importance. Hence, the manpower which could be profitably employed, will have to be software designers. As a matter of fact, by the end of the century, no worthwhile engineer can exist without a knowledge of computers and computer programming.

As in the case of hardware, the software has also undergone rapid changes. The introduction of Structured language, for example Pascal is possible with the microprocessor (Zilog 80). The limiting factor of software will be the ability of the design team to provide task specific, application oriented languages rather than the ability of microprocessors to execute them. The other software concepts with microprocessors are "networks and distributed processing" and "parallel processing" with two or three central processing units (CPU's).

With the ability of Very Large Scale Integration (VLSI), some of the primitives of a program can be so to say "wired in" the chip itself. Take for example a real time missile control. Most of the operations of the missile control can be part of the VLSI. Similarly, many situations in Defence like radar scanning, tank control, mines etc. can be integrated in the chip itself. The most trivial example of how a superior and sophisticated technology like the microprocessors is used, is the video games like space wars. All the software is written in the chip itself. This opens up huge possibilities when the hardware can supplement the software efforts.

8. The Microprocessor Applications.

Our imagination is the only limiting factor in microprocessor applications. In Western countries, this will be used in sophisticated Defence equipment and space craft. It will also be used in trivial applications like TV games, home computers etc. In between it will be used in telecommunications, weather analysis, crop analysis, text editing, newspaper editing, for books etc., so that a society based on exact information is possible. The individual in such a society, because of his ability to share in the knowledge, will be a better citizen in helping the Government. The politicians, ministers, bureaucrats, can all be benefited by such information explosion. Like any new technology brings in its wake beneficial as well as harmful aspects, this technology also has some disadvantages, but the policy makers should take this into view.

In our own country, these LSIs can be used in Telecommunications. An analysis made recently reveals that by the end of the century, the mails as they are being carried today, by aircrafts and trains, will be so overstrained that all the trains and aircrafts will have to carry only mail and not passengers. In this context, "electronic mail" becomes a necessity. Britain, Canada introduced this for various other reasons, but we have to do this for survival. Similarly, the stored program electronic exchanges for each village (cost will be immensely less than the present day systems), so that de-urbanisation becomes a possibility and they could be run from solar power. In the case of traction, for accident prevention, speeding of trains, ticketing etc. can be more conveniently done with these LSIs. Scores of examples can be cited for this. It is unfortunate that in our country nothing is being done about this.

The introduction of this technology may mean replacing jobs, but is not true. This only means that new kinds of talents would be required to man these installations rather than complete replacements. A new cadre of skilled workers would be necessary.

This analysis shows therefore that innumerable possibilities exist within our country to ameliorate the present situation by adopting this LSI technology. We will examine now, how far this could be done with our technology and with transfer of technology. These implications are analysed next.

9. Technology Transfer and What is it?

The technology transfer, in whatever area it may be, between developed countries and developing countries, is extremely assymmetric. We always want to buy and we have nothing to sell. This reduces us to the situation where we are faced with the worst form of feudalism. At least in the case of land, there are land reforms and agrarian reforms, but in the case of technology, there is no such effective codes, with the result that we have to pay continuously for what we want. Science and technology are knowledge about knowledge. In this respect, they are a better real estate than land itself. This anomaly, as far as we are concerned, has been discussed in many U.N. forums, and except for two international co-operations, there has been no worthwhile contribution to the Developing countries from Developed countries. As the years go by and as the technology develops, this situation will be worse and not better.

The reasons are many for this situation. The entire purpose of developed countries exploiting science and technology for their own use is different from developing countries, the societal structure, the motivation are all completely different and the pressures for advancing R&D in science and technology are also different.

10. <u>Technology Transfer for past 25 years</u>.

If we look at the history of the past 25 years or so when the developing countries have bought technologies from multinationals, we see that there are many dark spots. The entire purport of technology transfer is to improve the living conditions of majority of people. This has not been the result as we find to our dismay. The reasons may be social, political, national or international. This existing inadequacy has been entirely due to lack of integrated approach or policies by national and international institutions and, above all, a lack of internal technological muscle, that is local R&D.

11. <u>Case of Transfer of Technology in Electronics - India.</u>

In India, there has been a continuous import of technologies in Electronics, both in private and public sectors. Somehow or other, due to our own shortsightedness, the electronics industry has not contributed as much as it should have. Our methodology, in the past, and even now, is to import technology on cost benefit basis, or import substitution or foreign exchange savings, with the result that we have been ending up buying slightly older technolgies.

In order to highlight this, we can look at two major public sector undertakings in electronics, Bharat Electronics Ltd., Bangalore and Electronics Corporation of India Ltd. at Hyderabad. Both pursued different policies. Bharat Electronics Ltd. has built up an excellent production base on bought technologies without worthwhile R&D, whereas Electronics Corporation of India Ltd. has been set up completely with indigenous R&D without adequate production methods. Both are economically successful, but have contributed little to the future of electronics within the country. Surely, they have reasons of their own and they are mostly Governmental and their programmes are primarily motivated by immediate cost benefits. Now that they are mature, it is certain they will contribute substantially in the next decade. The most serious problem they have faced is the weak market. Our own inadequacies in the technology assessment is highlighted by the example of Semiconductor Complex, a Government of India undertaking for production of LSI and microprocessors and R&D, which is yet to take off after nearly nine years after its inception. This only means that our priorities happen to be different.

12. Science & Technology and R&D.

Science and Technology are important intervening variables that influence socio-economic development and national objectives of self reliance and Defence. We have a fullfledged Science & Technology plan. We have also a number of research laboratories under the Government. In spite of these, we buy technology continuously, and that too at high costs. This only means that our industrial needs are not adequately met by R&D or R&D plan is not such a cohesive one.

Whatever may be our internal structure, which can always be set right by proper planning etc., it is necessary that we develop a strong R&D expertise, so that negotiations on technology can be carried out on a bilateral basis. This is not an empty argment as the cost of technological dependance by the developing countries is easily $ 30,000 - 50,000 a year.

These are only direct costs. If we take the other indirect costs like royalty etc., the figure is enormous and is much more than the GNP of many countries put together.

13. Conclusions.

The future of Electronics is the age of LSI and Microprocessor. It is not known that what applications they will fulfil. In view of the low costs, almost all electronic applications will use the microprocessors. Some of these applications like in traction, telecommunications, are quite relevant for our country. They are not luxuries, but necessities.

In our country, we are yet to use the LSI's in any meaningful way. Buying technology continuously is a very costly process and without adequate R&D, we can neither be self-reliant nor can we negotiate on equal terms. We have to somehow or other build our own technological muscle in these areas.

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